Pressures on the Great Lakes Ecosystem

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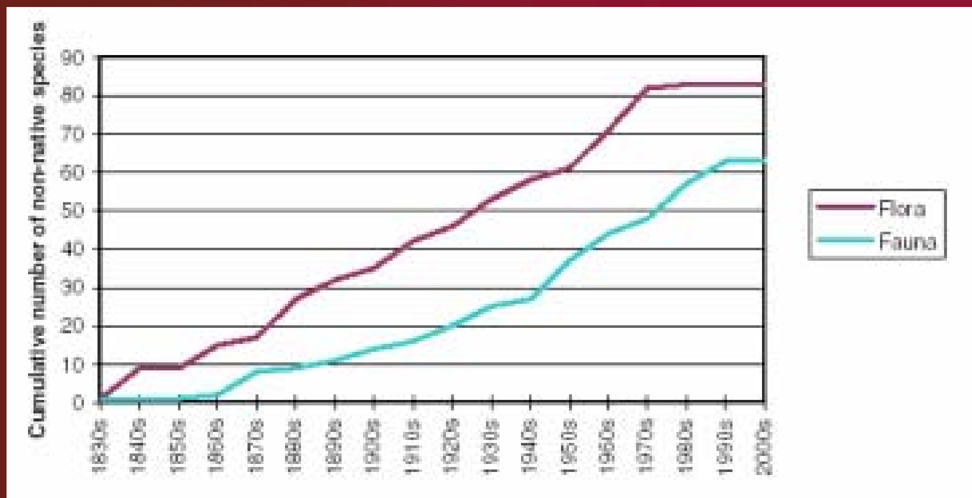
Good morning. I'm Donna Myers, with the U.S. Geological Survey, and I am very pleased to be here this morning and to speak to you about the major pressures that are impacting the ecological health of the Great Lakes.

Major Pressures on the Great Lakes

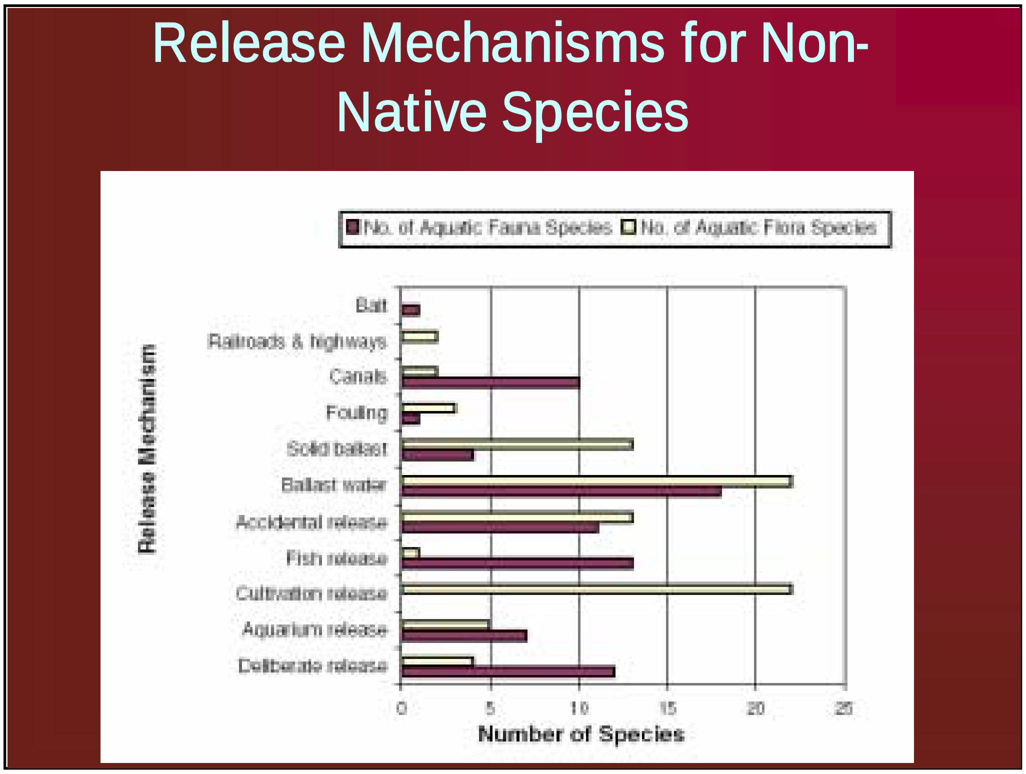
- Non-Native Species
- Toxic Contaminants
- Excessive Nutrients
- Physical Processes

Our assessment of the pressures being exerted on the Great Lakes is based on the findings from indicators. These indicators can be grouped into four main categories: Non-native species; toxic contaminants; excessive nutrients; and physical processes. We will take a look at several indicators within each of the pressure groups.

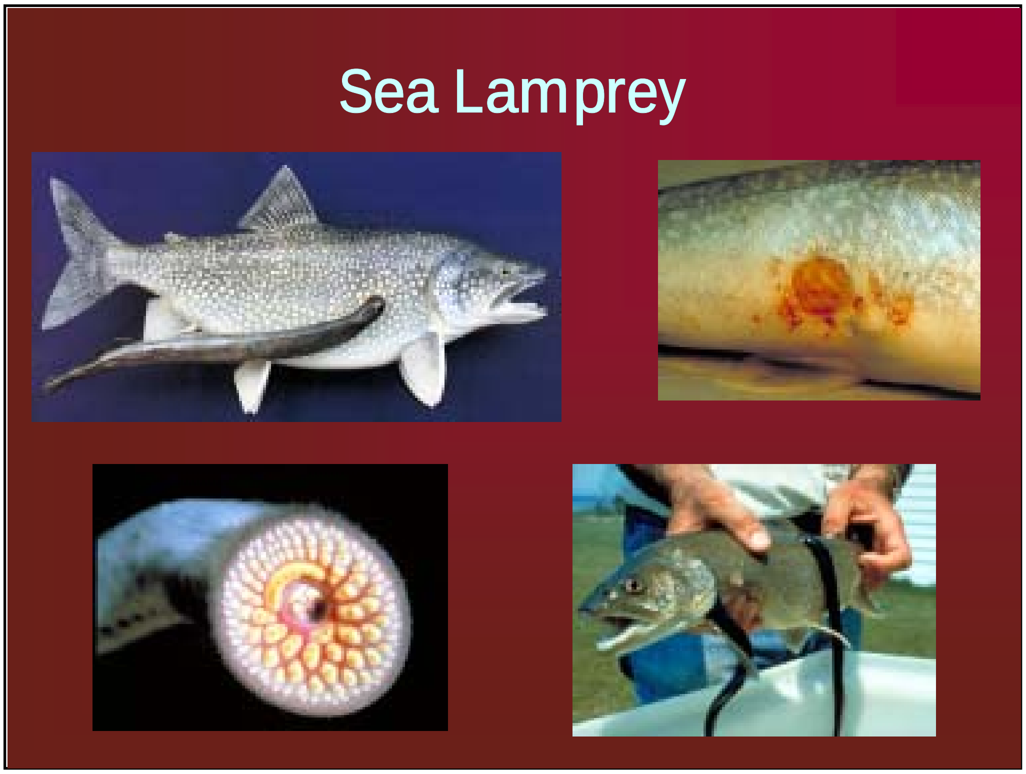
Cumulative Number of Non-native Species Introduced since the 1830's



First, we'll look at non-native species. Since the 1830s, there have been at least 146 non-native species introduced into the Great Lakes system; at least 63 non-native aquatic animal species and at least 83 non-native plant species. Many of these introduced species have been in the Great Lakes ecosystem for many years and have caused large changes. Familiar examples include the sea lamprey and its effects on large predator fish like lake trout; alewife, rainbow smelt, river ruffe and round goby all preyfish that comprise the diets of large predator fish, and the common carp, that has the capacity to greatly degrade its local environment making it inhospitable for native species. Recent invertebrate invaders that have entered the ecosystem include the spiny water flea, fishhook water flea, and of course the zebra and quagga mussels. Examples of non-native plant species are Eurasian watermilfoil and purple loosestrife. These plant species which are worthless as wildlife food are competing with native species that are valuable as wildlife food.

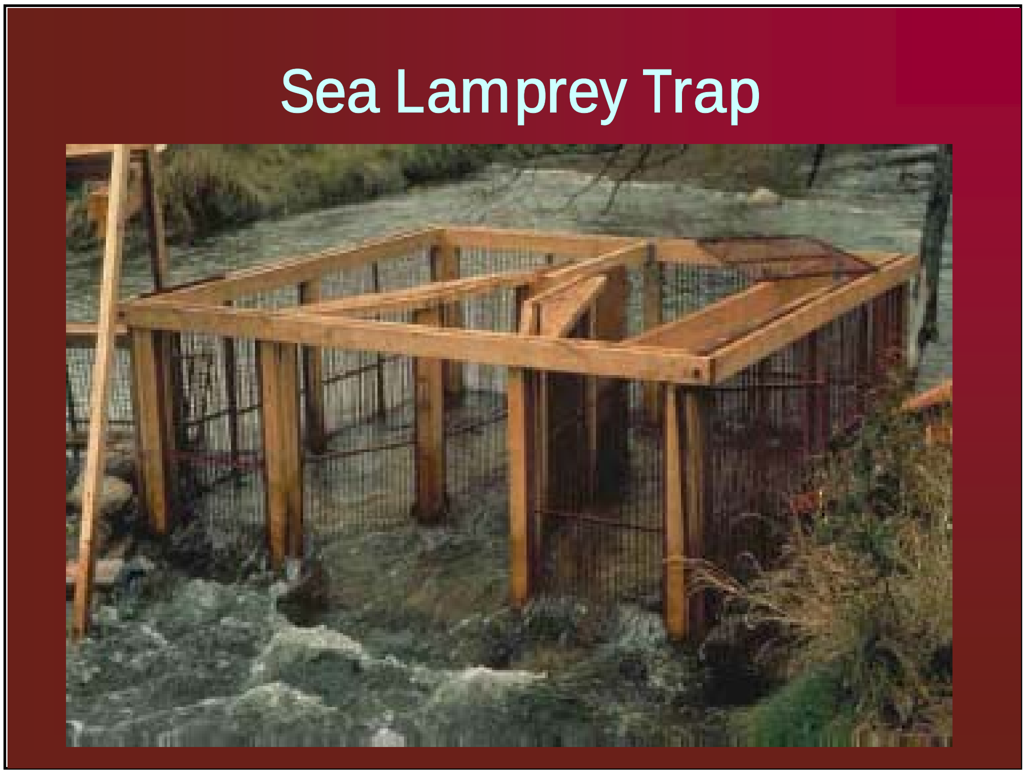


The main entry mechanisms for aquatic plants include ships discharging ballast water and solid ballast, from horticulture, and from aquariums. Even with recently implemented voluntary and mandatory ballast exchange programs in Canada and the United States, new species associated with shipping activities continue to be reported. Additional introductions of non-native species can be expected due to factors such as increasing global trade, the growth of aquaculture, and changes in water quality that may make create hospitable conditions for the establishment of non-native species. Recently the news media have reported that the Asian Bighead carp, a fish species that can potentially disrupt the fisheries of the Great Lakes, is poised and ready to invade the Great Lakes, being found in the Mississippi and Illinois Rivers, and just outside the Great Lakes basin in the Chicago Sanitary and Ship Canal. Keeping the Bighead Carp from invading the Great Lakes will require deliberate actions to prevent its entrance into Lake Michigan through Chicago waterways.



Sea lamprey, shown here attached to a Lake Trout, is one example of a non-native species that has altered the Great Lakes ecosystem and that has resulted in the expenditure of enormous amounts of time and money for its control. Sea lamprey predation, along with over harvesting of fish, resulted in the destruction of lake trout populations throughout the Great Lakes. As recently as 1995, lake trout restoration activities in northern Lake Huron were abandoned because so few lake trout were surviving to maturity. The low survivorship was due to attacks by sea lamprey.

In 1997, an integrated control strategy was initiated in the St. Marys River, which flows between Lake Superior and Lake Huron. Efforts include targeted application of a new bottom-release lampricide (a pesticide that kills only lamprey), enhanced trapping of spawning lampreys, and release of sterile-male lampreys. Results to date are encouraging.

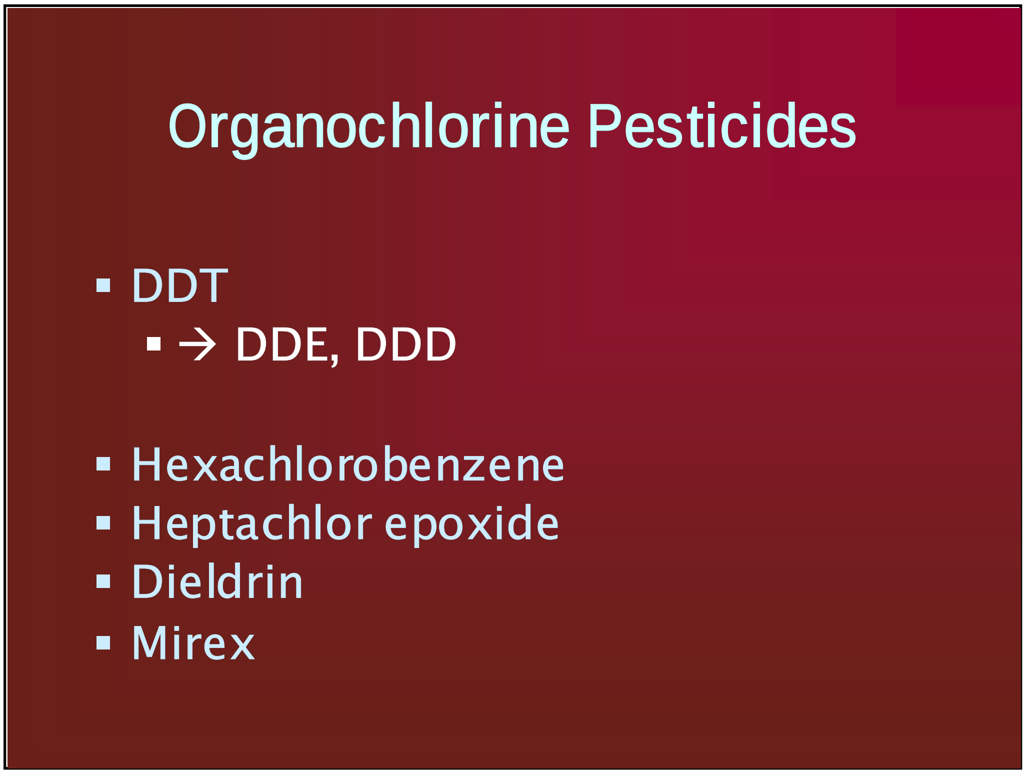


In the other Great Lakes, sea lamprey populations exhibit year-to-year fluctuations, but they are generally much below their peak abundances. Active control programs are required, however, to keep their numbers low enough for the survival of large, desirable fish species.

Let’s move on to contaminants.

We have seen information in Jan’s presentation about contaminants in edible fish. Now, I will relate to you additional information concerning toxic contaminants in other Great Lakes fish, birds and reptiles. These findings have implications for the Great Lakes ecosystem, and are relevant to how contaminants can bioaccumulate in the food web from prey animals that are lower on the food web up to the top predators of the food web.

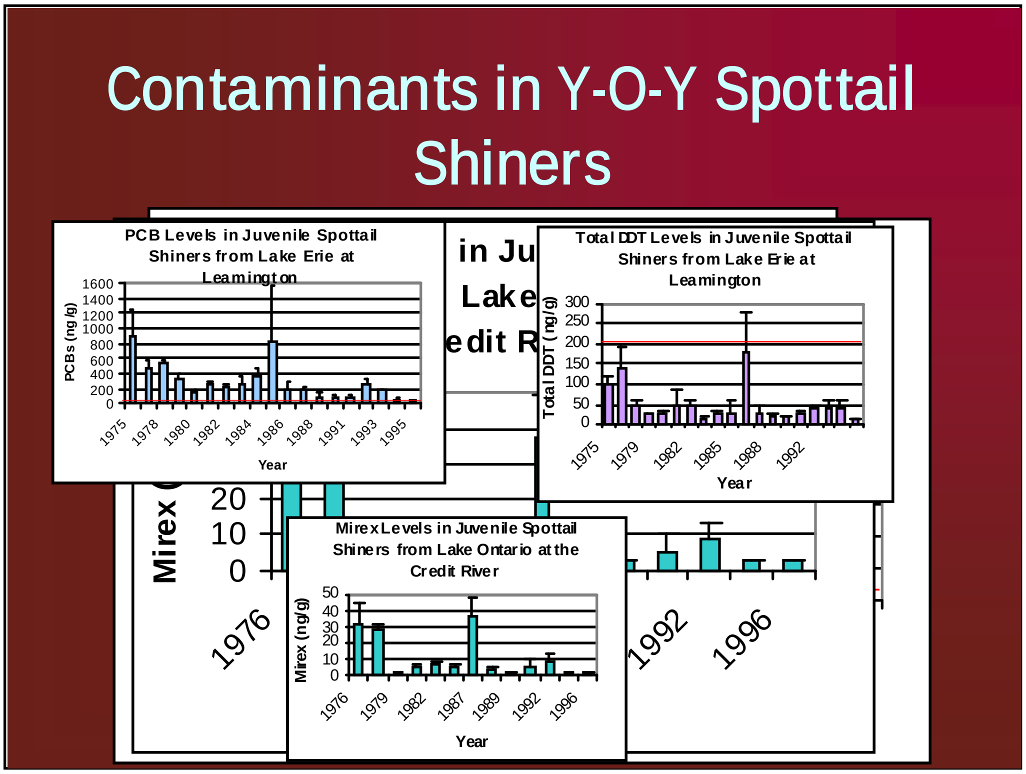
To start this discussion I will briefly describe the history of use and release of some of the toxic contaminants in relation to their current status and trends in fish, bird eggs, and snapping turtle eggs. PCBs and DDE are the compounds we will discuss.



First I want to tell you a bit about these contaminants. DDT is an organochlorine pesticide. Widespread use of DDT began in 1939, peaked in the 1960s, continued until about 1970, and greatly declined when use was cancelled in 1972. DDT degrades to DDE and DDD which also are bioaccumulative, toxic, and highly resistant to further chemical decomposition. Other organochlorine pesticides that I will discuss and which behave in a similar way to DDT, are hexachlorobenzene, DDE, heptachlor epoxide, dieldrin, and mirex.

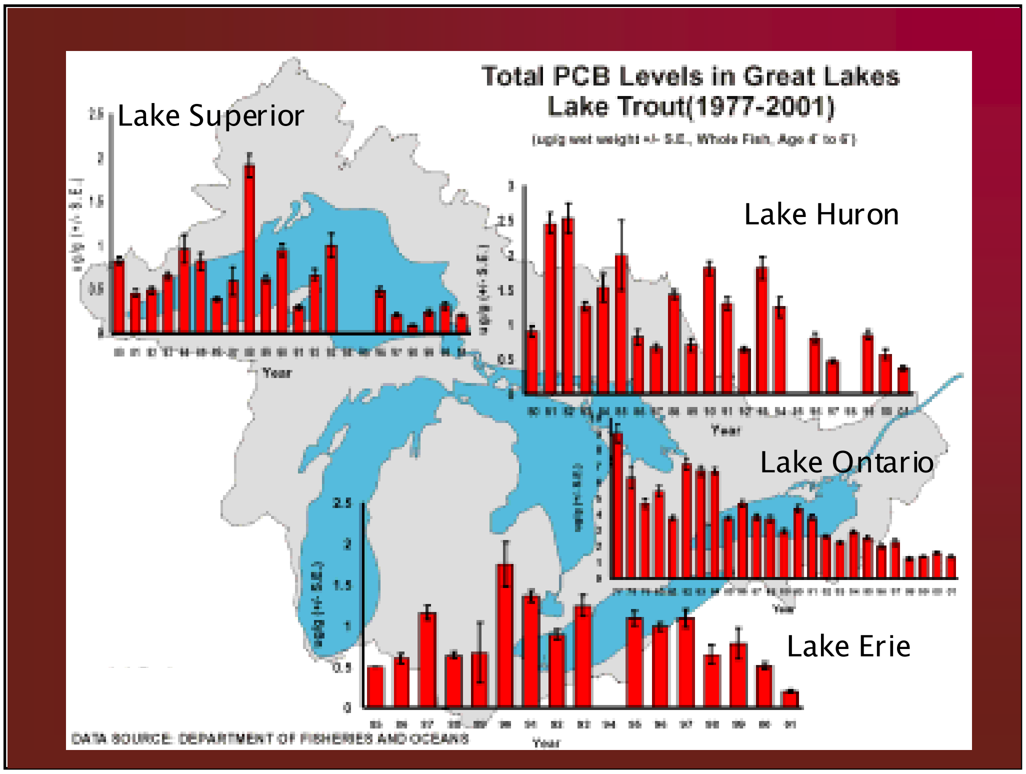
PCBs are another class or organochlorine compounds that are complex mixtures of as many as 210 possible variants (congeners). PCBs are constituents of various industrial products such as hydraulic fluids, electrical transformers (some of which are still in use or in storage), plasticizers, compressor oils, textile dyes, and waxes. In 1979, the manufacture and import of PCBs were prohibited in the United States. PCBs remaining in use are almost exclusively found in closed systems such as electrical transformers. Spills and leaks, however, may result in release to the environment. PCBs, like DDT are bioaccumulative, toxic, and highly resistant to further chemical decomposition.

Lastly, we use many different units of measure in this presentation. Most can be expressed as parts per billion or parts per trillion which is generally the same as concentration units of micrograms per gram (or parts per million) or nanograms per gram (parts per billion). These units express the mass of a contaminants per unit of body mass of an animal. That way, animals of different weights can be compared directly.

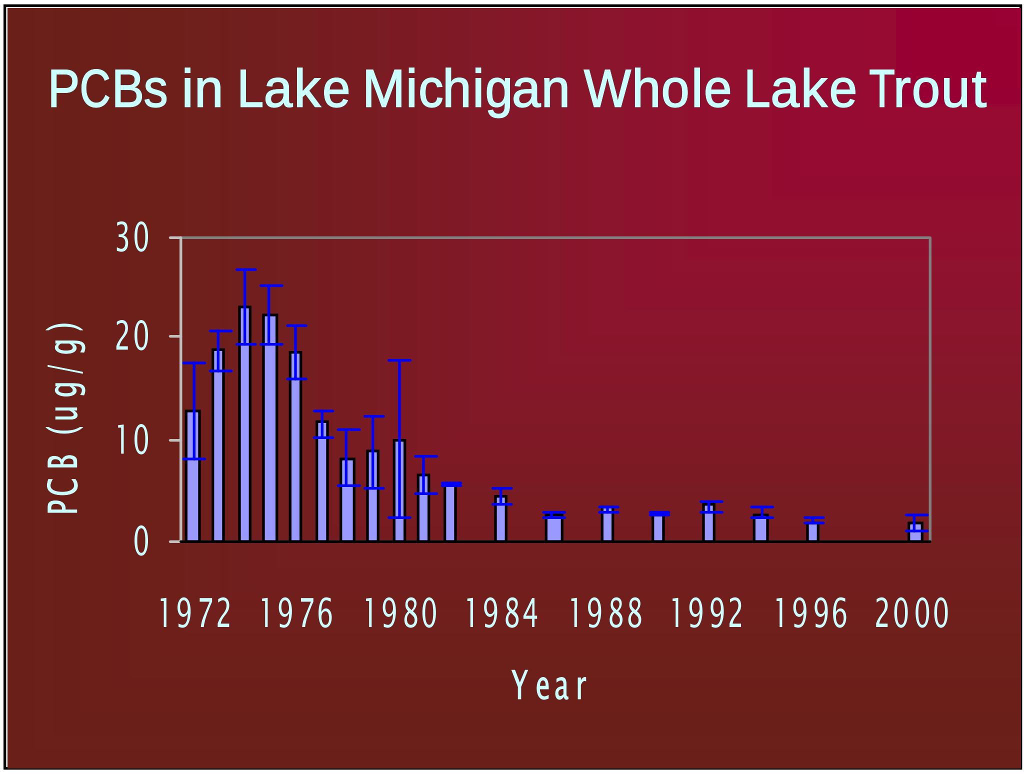


Lowest on the food web of the fish species monitored for contaminants are the preyfish called Spottail shiners. Spottail shiner minnows are common throughout the Great Lakes nearshore waters. Because their range is limited, any contaminants that accumulate in these fish are thought to be bioaccumulated from their local habitat over a time frame of several months during their first year of life. Young-of-the-year spottail shiners are used to monitor the relative amounts of toxic contaminants in the nearshore waters and provide a link in the bioaccumulation chain to predators higher in the food web. The concentrations of toxic contaminants in juvenile forage fish should not pose a risk to fish-eating wildlife. Guidelines for contaminant concentrations in fish have been established for the protection of fish-eating wildlife. The guideline for for chlordane is 500 ng/g, for HCB is 330 ng/g, for total DDT(DDT and its break-down products) is 200 ng/g; PCBs and HCH is 100 ng/g, for octochlorostyrene is 20 ng/g,, and for mirex is 5 ng/g.

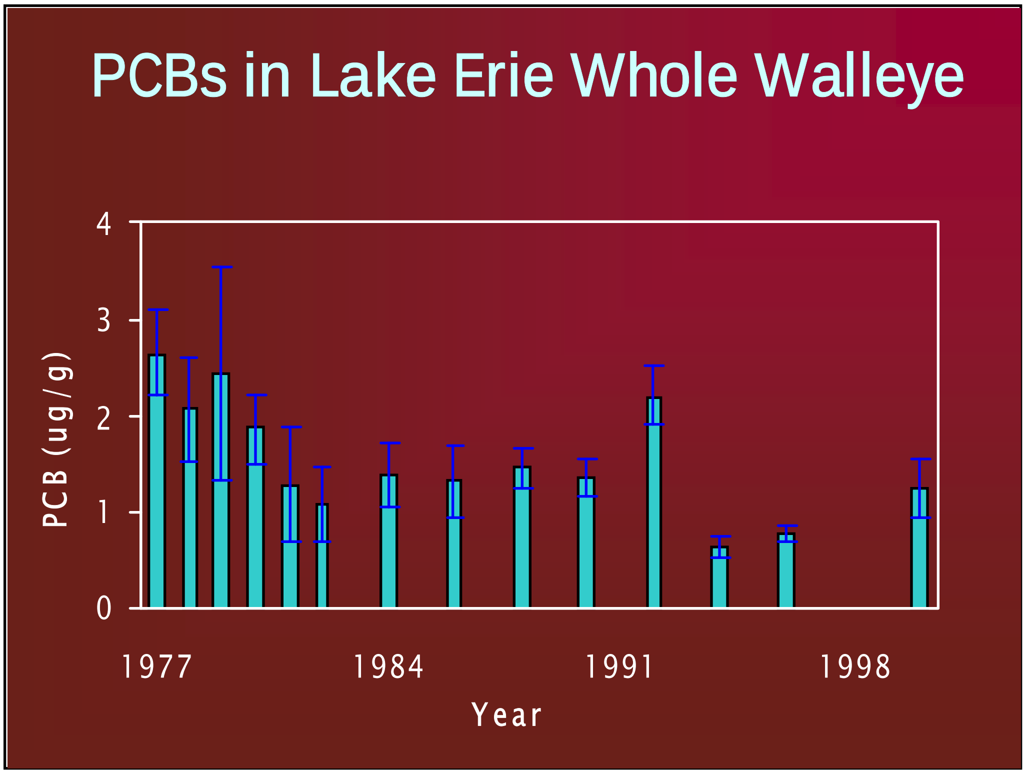
In each of the Great Lakes, PCBs were the contaminants most frequently found to fail the guideline. Total DDT is often detected and although the guideline was exceeded in the past, recent concentrations are well below the guideline. Mirex is detected only in Lake Ontario, where it exceeds the guideline. Trends in each of the Lakes for these toxic contaminants have been downward since the initiation of sampling in the mid to late 1970s.



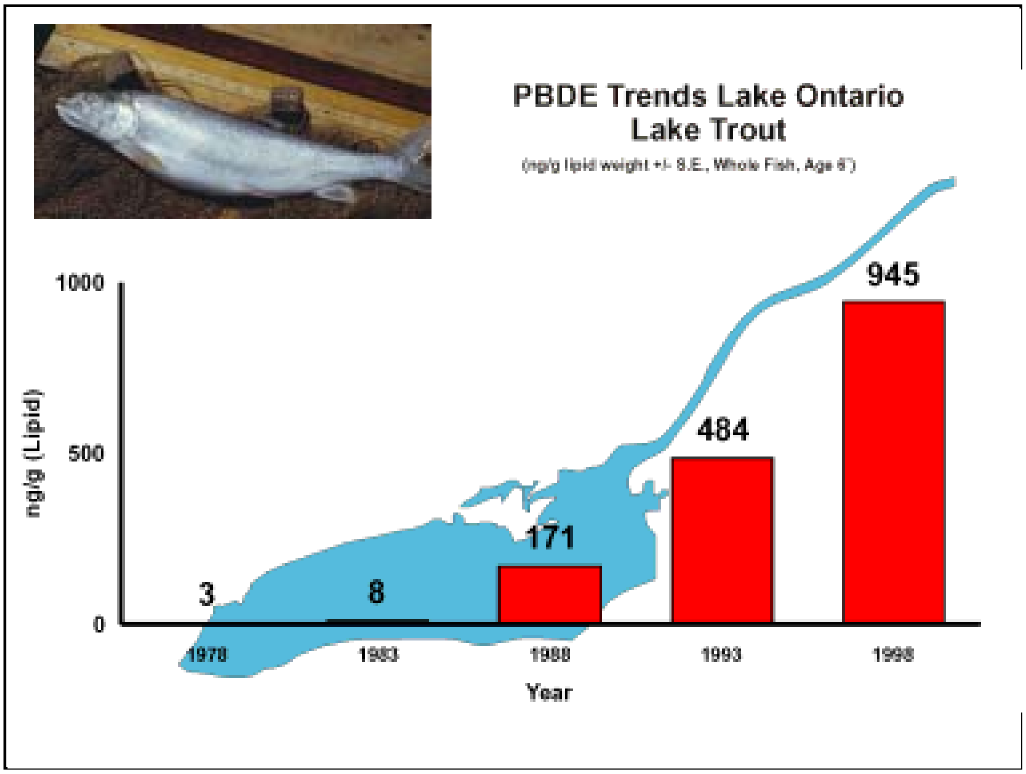
The concentration of contaminants in large, wide-ranging fish like Lake Trout can likewise indicate the relative availability of the toxic contaminants in the food web on the scale of a whole lakes or sub-lake basin. To increase our ability to follow year-to-year trends, fish of similar age or size are used in the monitoring programs in both the U.S. and Canada. Here we see the long-term trends in the concentration of PCBs in whole lake trout. For the information displayed here, data-collection began in 1977 for Lake Ontario, in 1980 for Lakes Superior and Huron, and in 1985 for Lake Erie. Data from Lake Ontario shows generally declining levels of total PCBs over time in Lake Trout. (Note that the concentration scale on the y-axis for Lake Ontario is higher than for the other lakes.) There is some question about recent years, during which the declining trend does not appear to be continuing. The trends for the other lakes are likewise downward although more variable from year to year than in Lake Ontario.



Similarly, for Lake Michigan, the available data extend back to 1972, during which time the Great Lakes were likely to be the most highly contaminated with PCBs and other chemicals than at any other time. PCB levels have declined consistently from 1971 through 2000. Current PCB levels are approximately 8% of those found in similarly sized fish in 1974, the year with peak concentrations. Likewise, although not shown here, current DDT levels are about 5% of those observed in 1972. Note the scale on the y-axis for Lake Michigan is highest among the lakes. DDT levels also have dropped (graphic not shown).

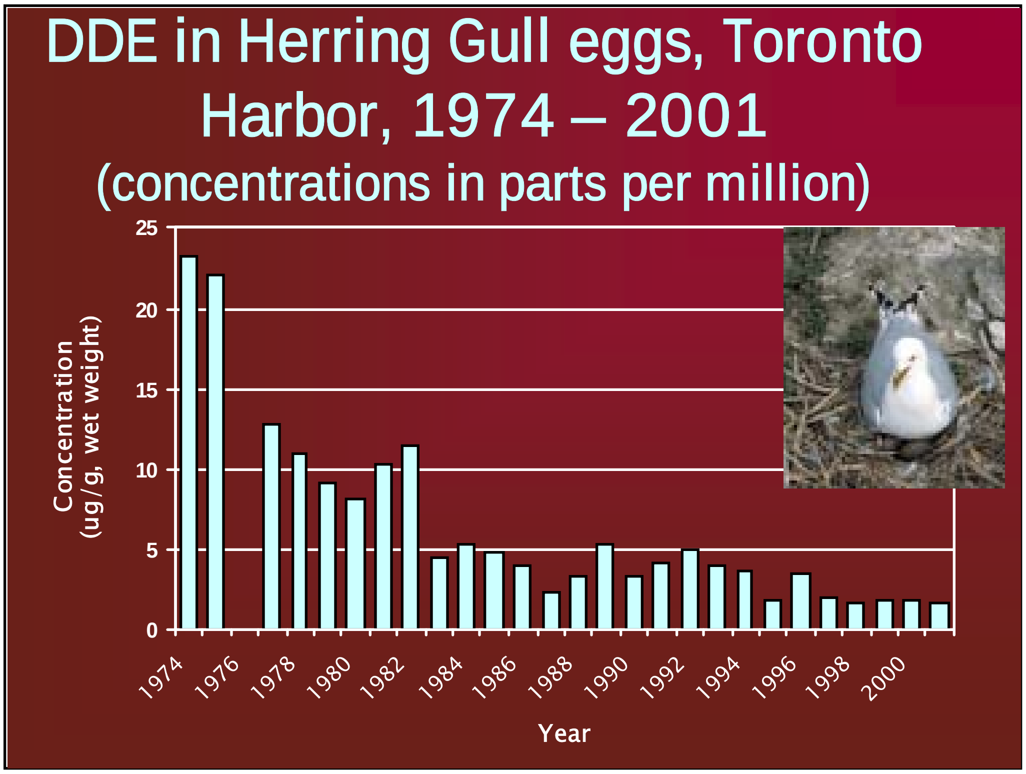


In Lake Erie, walleye are the dominant top predator fish, but because their body composition contains less fatty deposits than do lake trout, they tend to accumulate fewer toxic organic chemicals. Since 1977, PCB concentrations have generally declined in walleye. There appears to be an increasing trend from 1994 through 2000, but recent concentrations are about one-half what they were in the late 1970s.

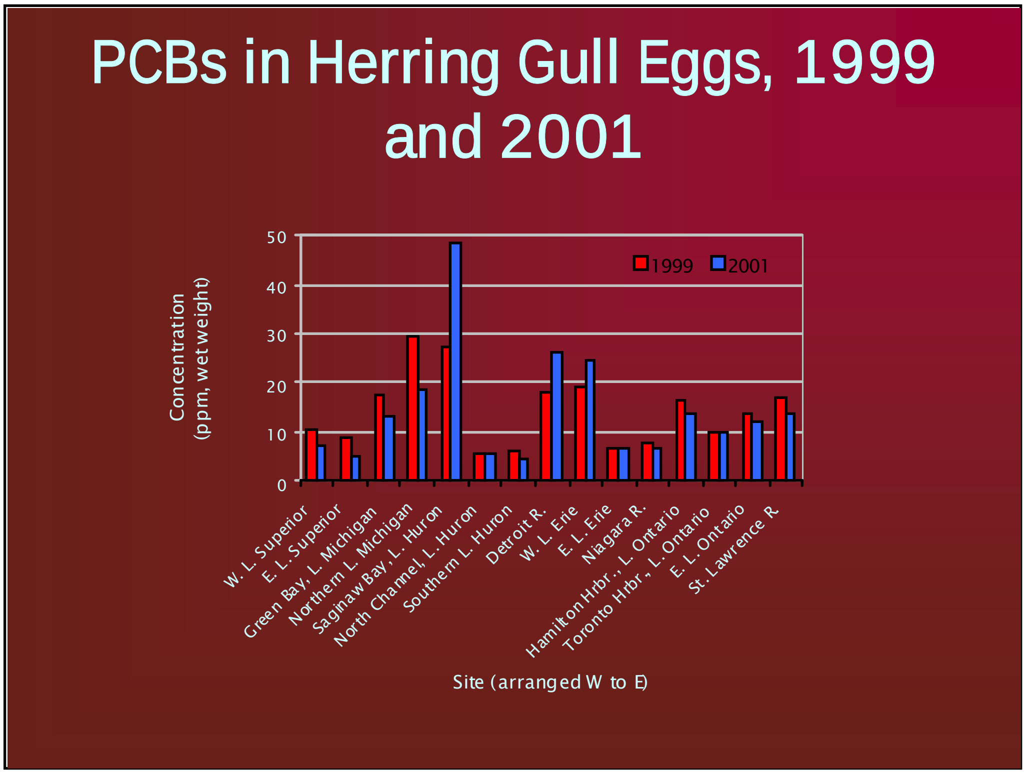


Lest we get the impression that the problem of toxic contaminants in the Great Lakes has been resolved, or that it is not as important as it once was, I would call to your attention the emerging issue of PBDEs, which stands for Poly-Brominated-Diphenyl-Ethers. These are a class of compounds used in a wide variety of manufactured products, perhaps most widely used as flame retardants. Like PCBs, some PBDEs could be highly toxic (we aren't sure yet), and they are known to be bioaccumulative and resistant to degradation in the environment.

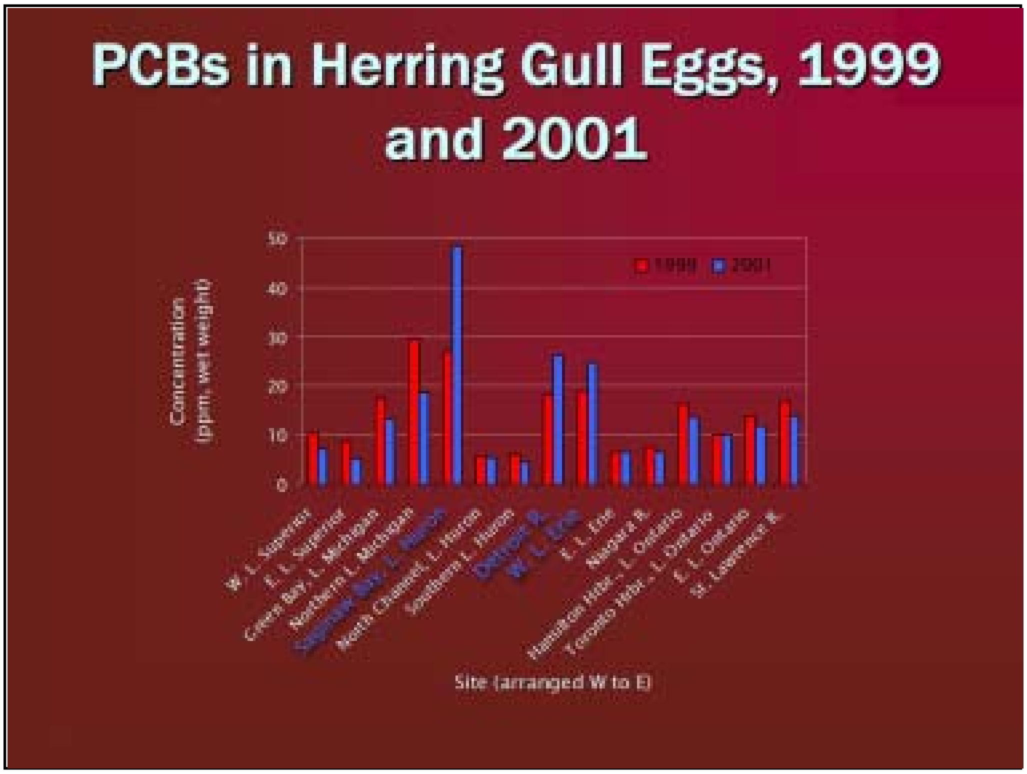
A disturbing trend is displayed here for the concentration of PBDEs in lake trout from Lake Ontario. Samples of archived Lake Ontario whole lake trout, representing the time period from 1978 through 1998 were analyzed. Levels increased from 3 ng/g lipid in 1978 to 945 ng/g lipid in 1998. There are 1,000 nanograms in a μιχρογραμ so 1,000 ng/g is equivalent to 1 ug/g. With that conversion in mind, we can compare PBDEs in Lake Ontario Lake Trout to PCBs in Lake Ontario Lake Trout and to Lake Trout in the other Great Lakes. Comparatively, PBDEs are found in Lake Trout in Lake Ontario at about the same concentrations as PCBs are found in Lake Trout in three of the five Great Lakes, including Lake Ontario. This gives rise to additional concerns for their apparent upward trends. This graph also emphasizes the importance of archived fish tissue samples for reconstructing trends in emerging contaminants.



The Herring gull egg-monitoring program has provided researchers and managers with another powerful tool to evaluate change in contaminant concentrations in Great Lakes wildlife. The long-term data show that concentrations of DDE, a breakdown compound of DDT, has declined by more than 90% in Herring gull eggs from Toronto Harbor since the program began tracking trends in 1974. Similar trends have been observed in other Lakes for most contaminants whereby contaminants have declined from 50 to 90 percent from 1974 to 2001.



A comparison of the most recent data on concentrations PCBs in Herring Gull eggs from sites across the Great Lake from west to east, showed that at 12 of the 15 sites, concentrations of PCBs were lower or the same in 2001 (blue bars) compared to 1999 (red bars).

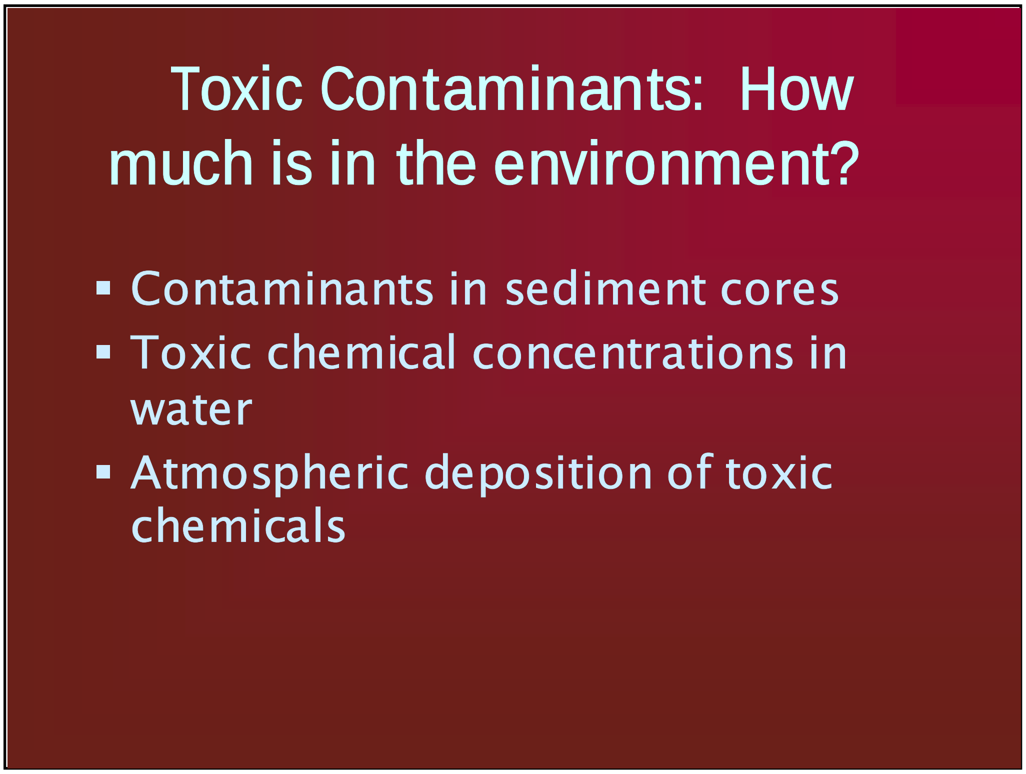


Higher concentrations in 2001 than in 1999 were found at collection sites on Saginaw Bay in Lake Huron, in the Detroit River, and in western Lake Erie. In addition to PCBs, other contaminants assessed in this project included hexachlorobenzene, DDE, heptachlor epoxide, 2,3,7,8 TCDD (dioxin), dieldrin and mirex. Dioxin or 2,3,7,8 TCDD, is an organochlorine compound that is a product of the combustion of plastics and similar materials or a residue from paper manufacturing.

Total PCB concentrations (parts per million) in Snapping Turtle eggs from selected sites and years

Site	YEAR			
	1984	1989-91	1998-99	2001
Algonquin Pk. (Reference)	0.187	0.018	0.02	0.02
St. Clair NWA, (Lake St. Clair)	1.095	–	–	–
Turkey Creek, Detroit River	–	–	–	1.832
Wheatley Harbor, Erie	–	–	–	0.413
Rondeau Provincial Park, Erie	1.093	0.617		–
Cootes Paradise, Ontario	1.315	3.575	2.956	–
Lynde Creek, Ontario	–	1.43	–	–
Akwesasne, St. Lawrence	0.869	3.946	6.373	–

While other Great Lakes wildlife species may be more sensitive to contaminants than snapping turtles, compared to snapping turtles, there are few other species that are as long-lived, as common year-round, that inhabit as wide a variety of habitats, and yet are limited in their movement between wetlands. Snapping turtles are also at the top of the aquatic food web and they bioaccumulate contaminants. Comparing PCB levels in turtle eggs from Great Lakes wetlands to a reference wetland not connected to the Great Lakes (Algonquin Park in Ontario), you can see that contaminants in snapping turtle eggs from Great Lakes wetlands were about 2 to 60 times higher than in the reference wetland. In addition, levels of PCBs and DDE in turtle eggs from Cootes Paradise (on Lake Ontario) appear to have increased significantly from 1984 to 1990-1991. Also, an increasing trend for PCB levels was measured in turtle eggs from the Akwesasne wetlands from 1984 to 1998-99.



Having looked at the status and trends of toxic chemicals in some of the representative Great Lakes fish and wildlife, we will now consider their presence in the non-living media, that is, in sediment cores, the open water column, and the atmosphere.

For this discussion we will use concentration units of micrograms per liter of water (or parts per billion) or nanograms per liter of water (parts per trillion). These units express the mass of a contaminant per unit volume of water. For atmospheric deposition, we will describe the concentration of contaminants in terms of picograms per cubic meter (parts per trillion) and the deposition of contaminants (or the loading) in terms of kilograms per year (the mass deposited annually.)

Sediment Quality Index (SQI) Scores – 1997 Samples

Lake and Basin	SQI Score
Erie	
Western	85
Central	86
Eastern	95
Ontario	
Niagara	67
Mississauga	66
Rochester	70
Kingston	87

Scale: 0 = Poor, 100 = Excellent

A Sediment Quality Index has been developed based on metrics used in the recently approved Canadian Water Quality Index. The metrics represent the concentration of contaminants in sediments expressed as their potential toxicity to bottom dwelling organisms. The concentration at which toxicity is likely to occur was taken from guidelines developed to protect aquatic life. The SQI incorporates three elements: Scope, that is, the percentage of contaminants in a sample that failed to meet established guidelines; Frequency, that is, the fraction of samples expressed as a percentage of the total number of samples that failed to meet the guidelines at a group of sites; and Amplitude, that is, the magnitude by which the samples concentrations were higher than the guidelines.

0-40 = poor
40-60 = marginal
60-80 = fair
80-95 = good
95> = excellent

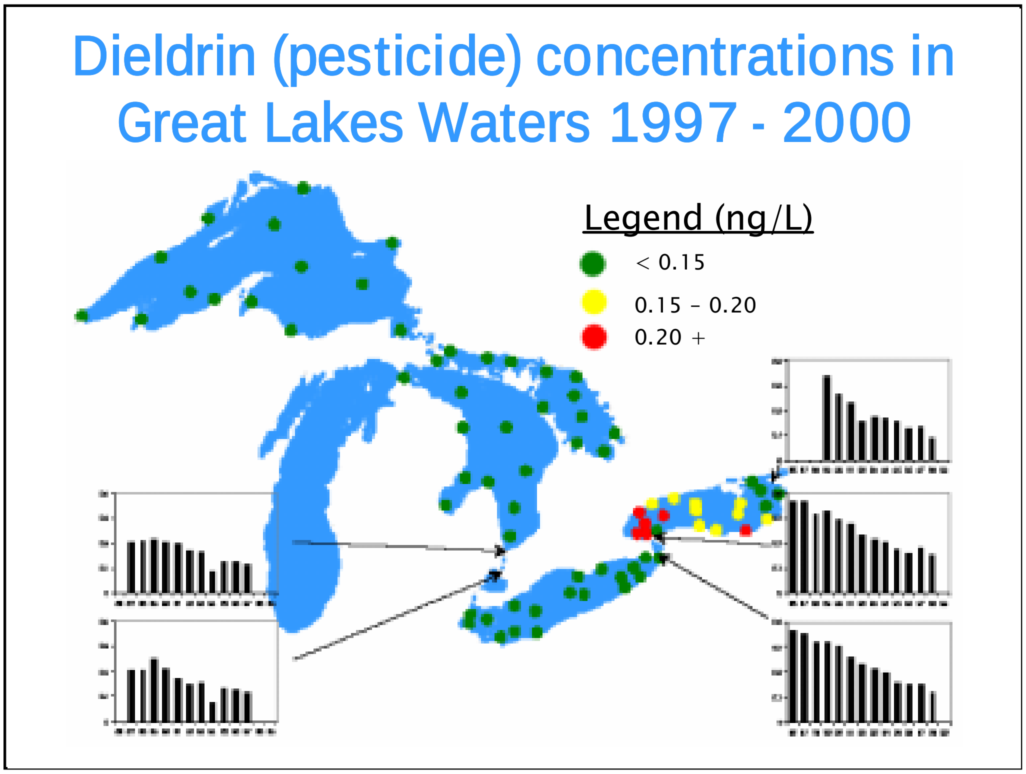
From a survey of sediments in the open waters of Lakes Erie and Ontario in 1997, analyses for 34 chemicals with guidelines were available for inclusion in the SQI calculations. Eastern Lake Erie scored excellent with a 95 score, while the Niagara basin of Lake Ontario scored only fair with a score of 67. Other basins were assessed intermediate between those two.

SQI scores for Five Areas of Concern in the U.S.

SITE	Lake	SQI Score
Buffalo River, NY	Erie	93
Saginaw River and Harbor, MI	Michigan	58
Ashtabula River and Harbor, OH	Erie	36
Sheboygan River and Harbor, WI	Michigan	29
Grand Calumet River / Indiana Harbor, IN	Michigan	25

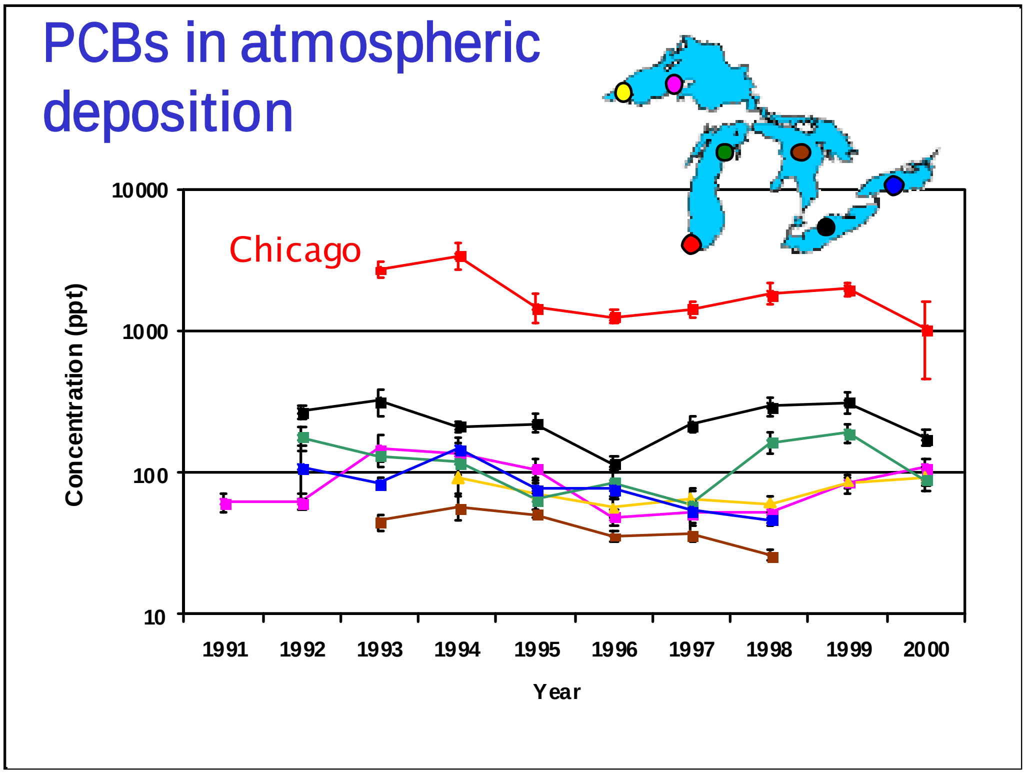
Scale: 0 = Poor, 100 = Excellent

When sediments representing open waters are compared with sediments representing selected Areas of Concern in the U.S., SQI scores were generally lower in the Areas of Concern, indicating more contamination in those areas compared to the open lake sediments. Scores ranged from 24.5 for the Grand Calumet River/Indiana Harbor to 58 in Saginaw River and Harbor. The only excellent score in an Area of Concern was in the Buffalo River with a score of 93.2. Some caution is warranted, however, because the data were associated with samples collected in 1987 to 1989.



Now we turn our attention to concentrations of contaminants in water. Many of the same toxic chemicals that we have been discussing in fish, wildlife, and sediments are also present in Great Lakes water. As a result of various ecosystem health assessments, a comparatively small number of these toxic contaminants have been identified as "critical pollutants." Organochlorine compounds comprising pesticides and PCBs, several of which are on various critical pollutant lists, have declined in the Great Lakes in response to management efforts. Aerial concentration patterns illustrate the wide-spread and localized nature of nature of some contaminants like dieldrin. Dieldrin, an organochlorine pesticide, was detected in water at all open lake and connecting channel sites. Concentrations throughout the Great Lakes, however, have decreased by more than 50% between 1986 and 2000, and are still declining. However, concentrations of dieldrin at some sites exceed New York State's water quality criterion for the protection of human consumers of fish by a factor of 50 to 300 times. Dieldrin (and aldrin which degrades to dieldrin) were some of the most widely used pesticides prior to their cancellation for surface use in 1974. Most remaining products were cancelled by 1987, the last product being cancelled in 1991.

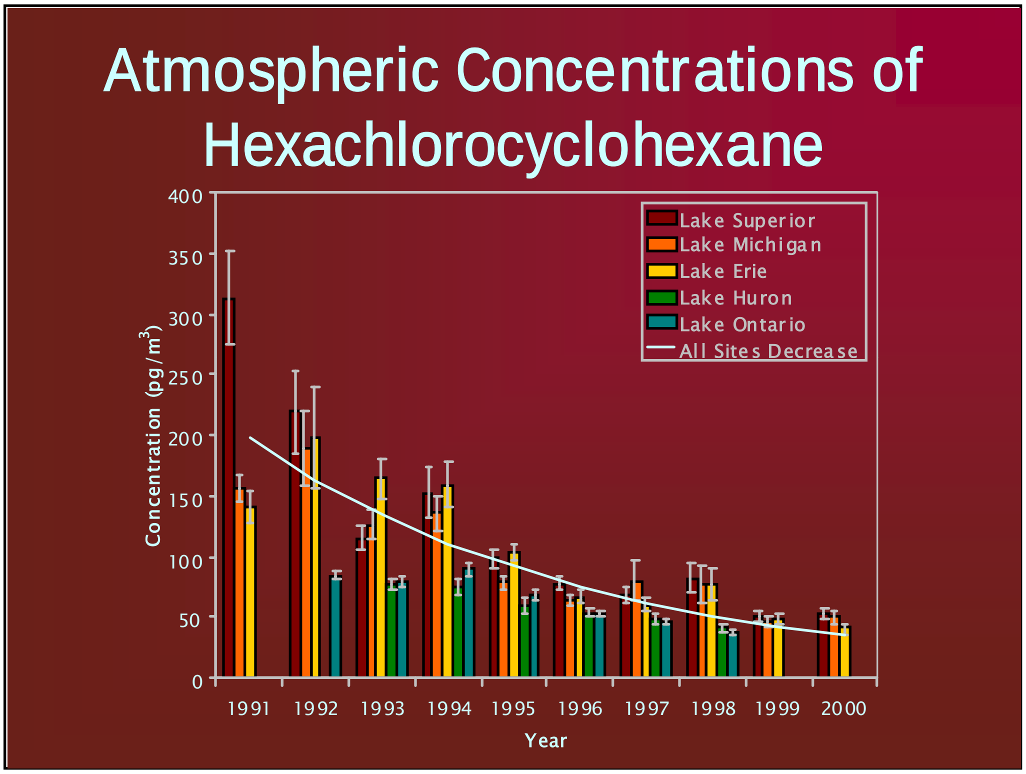
You have earlier seen data on PBDEs in lake trout. In the open waters, there are also concerns about endocrine-disrupting chemicals, pharmaceuticals, and in-use pesticides.



Lastly, we will discuss concentration and deposition of toxic contaminants from the atmosphere to the lakes. The purpose of the atmospheric deposition indicators are to estimate the annual average concentrations, loadings, and trends in priority toxic chemicals deposited from the atmosphere to the Great Lakes. This information helps to determine the potential toxic impacts from the atmosphere on human and ecosystem health as well as to track progress toward virtual elimination. Most of the monitoring sites are located far away from point sources such as cities and these "master stations" represent regional atmospheric deposition quality, rather than the quality and amount of atmospheric deposition near cities.

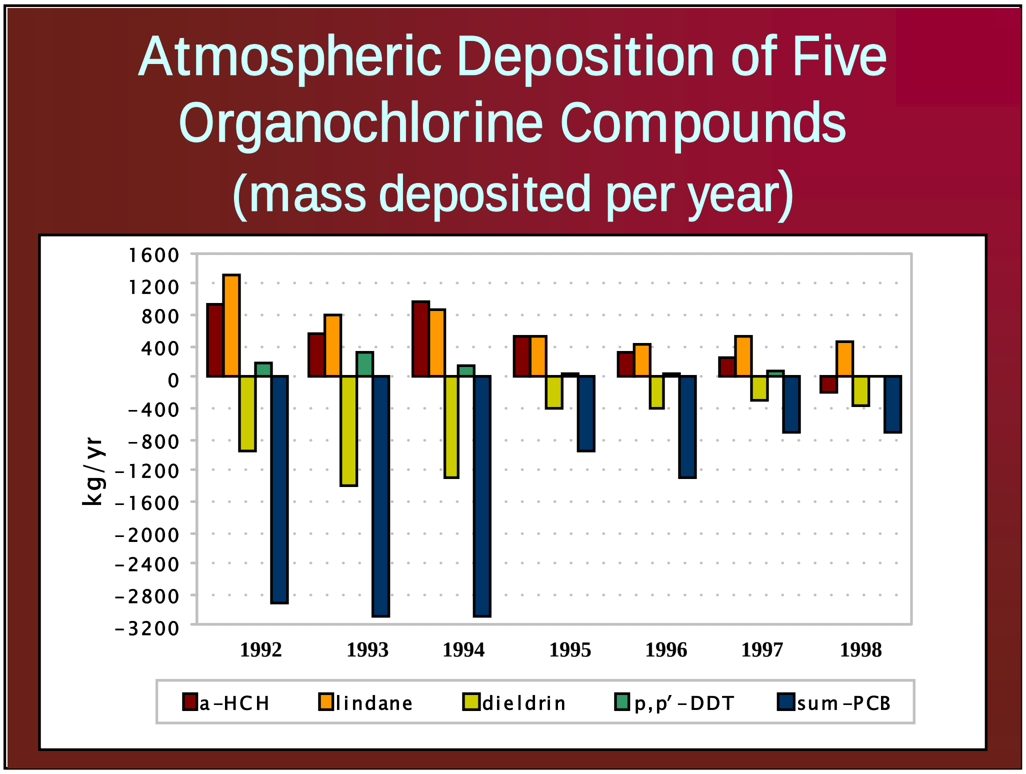
The units of concentration used here are picograms per cubic meter or parts per trillion. These units describe the mass of contaminant per unit volume of air

From 1991-92 to 2000, the concentrations of PCBs varies with a general downtrend at most Master stations. Most noticable, are concentrations of PCBs at the site near Chicago. These concentrations are about 10 times higher than at the regional sites (note the log scale). This indicates that atmospheric deposition near cities like Chicago may be much greater than is atmospheric deposition away from cities.



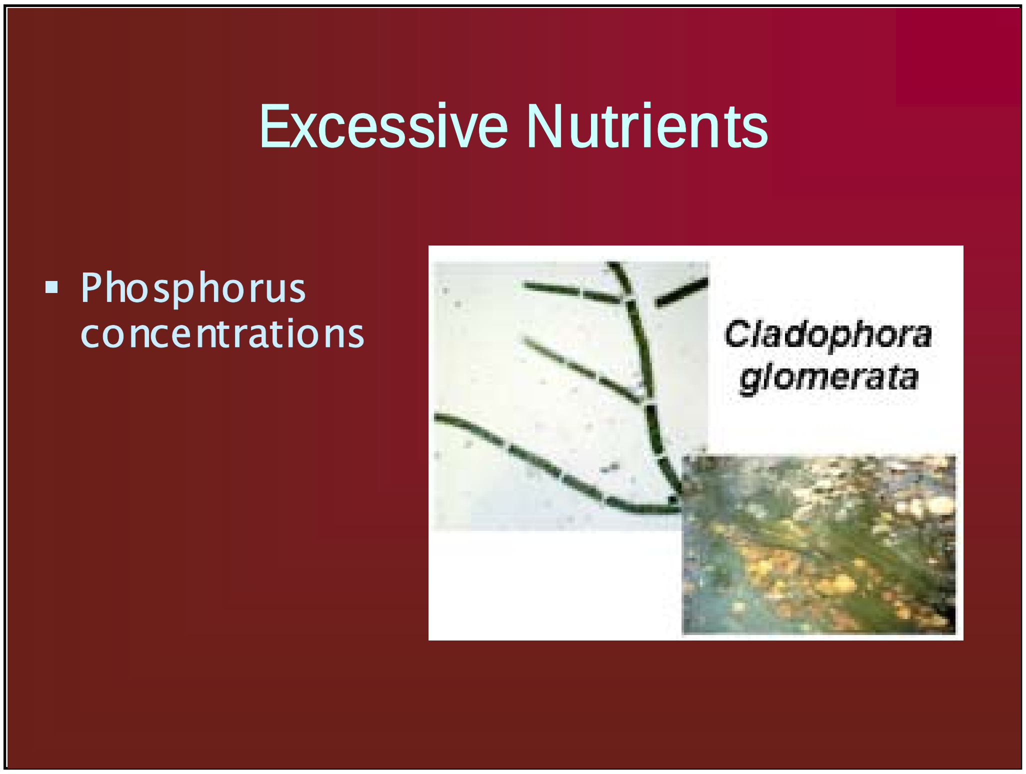
Like PCBs, a decreasing trend is noted for concentrations of hexachlorocyclohexane from 1991-2000 in all the Great Lakes. HCHs are organochlorine pesticides and there are four isomers, one of which is lindane. There are still a few active uses of lindane for head lice and to treat seeds, and therefore, there are active sources to the environment.

Trends in other contaminants like trace metals are mixed, with some metals decreasing in concentration while others show year to year variability. Residual sources of PCBs remain in the US, Canada, and throughout the world. Other contaminants such as PAHs and metals continue to be emitted.



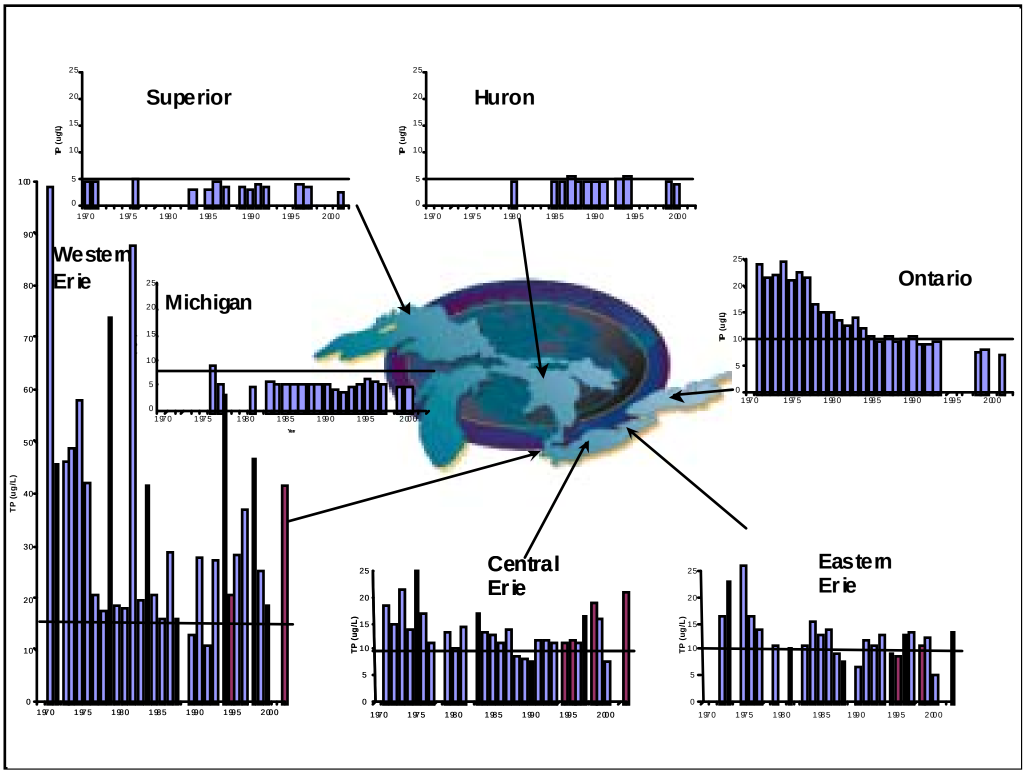
Now lets look at atmospheric deposition, or the mass of contaminants deposited to the Great Lakes per year. PCBs and organochlorine pesticides are hydrophobic, or in other words, they don't dissolve very well in water and this affects their concentration and movement in the Great Lakes waters. These contaminants can easily transfer between water and air depending on physical constants such as vapor pressure and on chemical concentration gradients between air and water. In this graph, the bars below the zero line indicate that the Great Lakes are loosing more of a contaminant to the atmosphere than they are gaining from the atmosphere. A bar above the zero line indicates that the Great Lakes are gaining more of the contaminant from the atmosphere than they are loosing to the atmosphere. This occurs when the concentration in air is lower than that in water which happens after the main sources to the air have been cut off and the air becomes "cleaner" relative to the water.

From 1992-98, the total amount of atmospheric deposition to the Great Lakes Basin from all five contaminants shown in this figure declined or more of the contaminant was lost from the lakes than was gained. By 1998, positive deposition to the lakes of only p,p'-DDT and lindane were measured and the gain in DDT is almost imperceptible in this graph. Both PCBs and dieldrin are being lost from the lakes consistently each year from 1992-98 although the amount of loss appears over time. This may happen when the concentrations in the atmosphere and the concentrations in the lake water are approaching equilibrium.



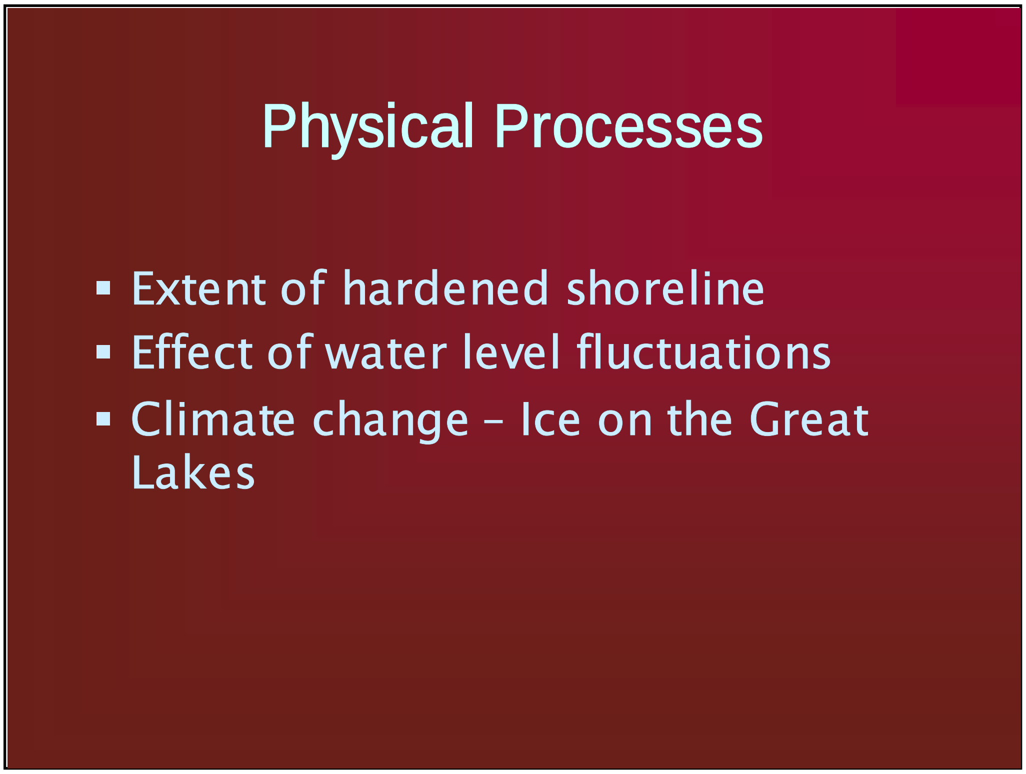
Lastly, we will examine the status and trends in phosphorus concentrations in the Great Lakes. Phosphorus is a plant nutrient and stimulates the growth of algae and other aquatic plants. Excessive amounts of phosphorus can result in what is called “eutrophication” or the process of lake enrichment. Symptoms of eutrophication include algae blooms, unwanted growths of other aquatic plants, and fish kills from the decay of these plants and subsequent loss of oxygen in bottom waters of the lakes (hypoxia or anoxia).

Total phosphorus concentration is expressed in units of micrograms per liter which is the same as parts per billion. This is equivalent to the mass of phosphorus in each liter of lake water.

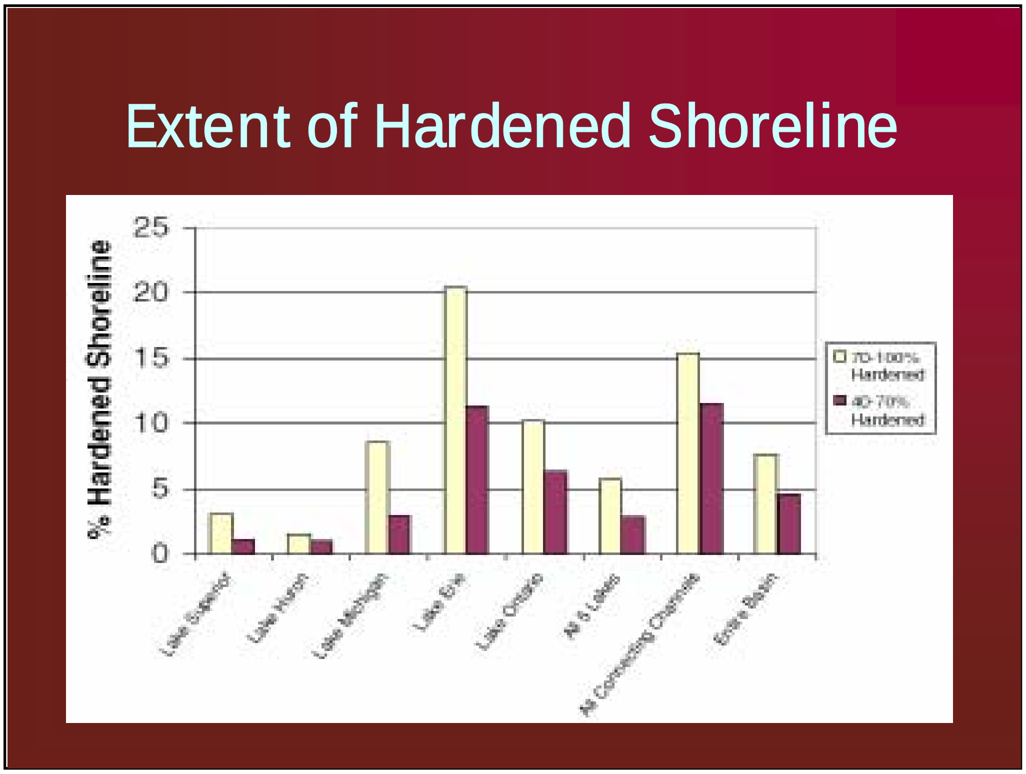


The 1978 amendments to the Great Lakes Water Quality Agreement established goals for total phosphorus concentrations in the Great Lakes. Large amounts of money have been expended to control the loading of phosphorus to the Great Lakes, largely by reducing concentrations in wastewater and in agricultural runoff. These management actions have improved the lakes by reducing phosphorus concentrations over time. The GLWQA also established total phosphorus concentration goals (guidelines) for each of the lakes and for the three subbasins of Lake Erie (the western, central, and eastern subbasins.) These guidelines are the concentrations, that if met, would keep nutrient enrichment at bay in the lakes. For Lakes Superior and Huron the guideline is 5 ug/L, for Lake Michigan it is 7 ug/l, for Lake Ontario and the central and eastern basins of Lake Erie it is 10 ug/L, and for the western basin of Lake Erie it is 15 ug/L.

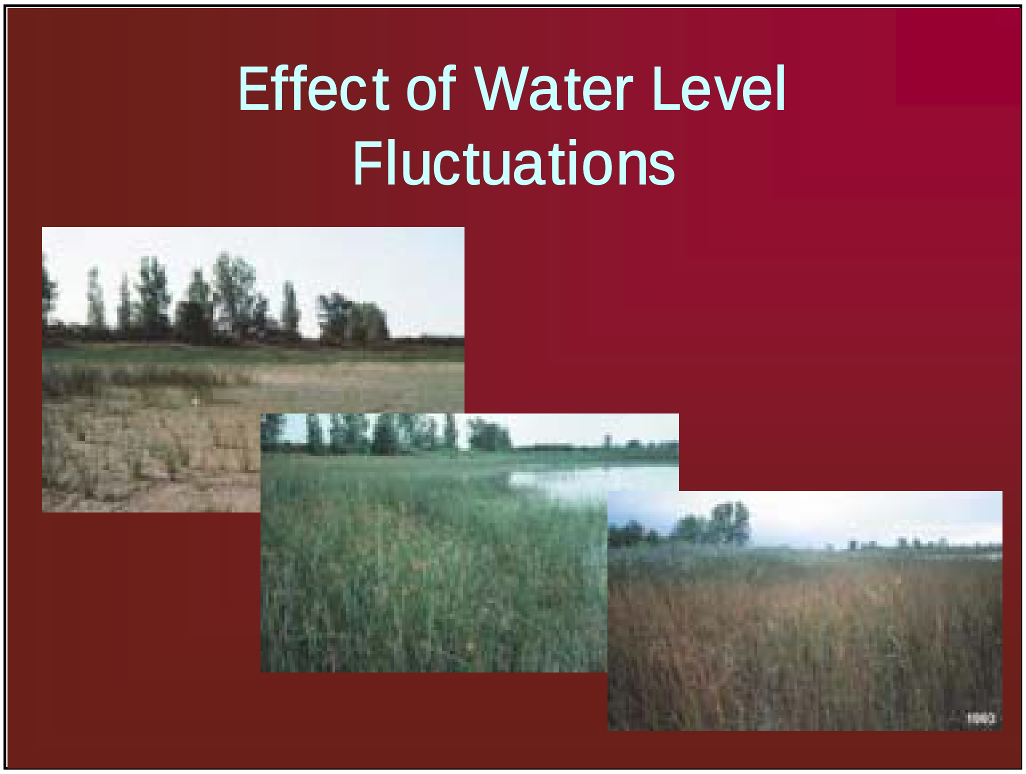
The total phosphorus guidelines for four of the five Great Lakes are at or are below the established guidelines in recent years. In Lake Erie's western basin, concentrations of total phosphorus were much above the guideline in recent years. In the central and eastern basins of Lake Erie, total phosphorus concentrations were more often above than below the guideline in recent years. The U.S.EPA-Great Lakes National Program Office recently launched an investigation to determine the causes of the return of elevated total phosphorus concentrations to Lake Erie as reports of anoxic conditions in Lake Erie's central basin have raised public concerns for the health of the lake.



Now let us take a look at the final group of pressure indicators: Physical processes. I will describe three types; extent of hardened shoreline, effect of water level fluctuations, and ice on the Great Lakes as an indicator of climate change.



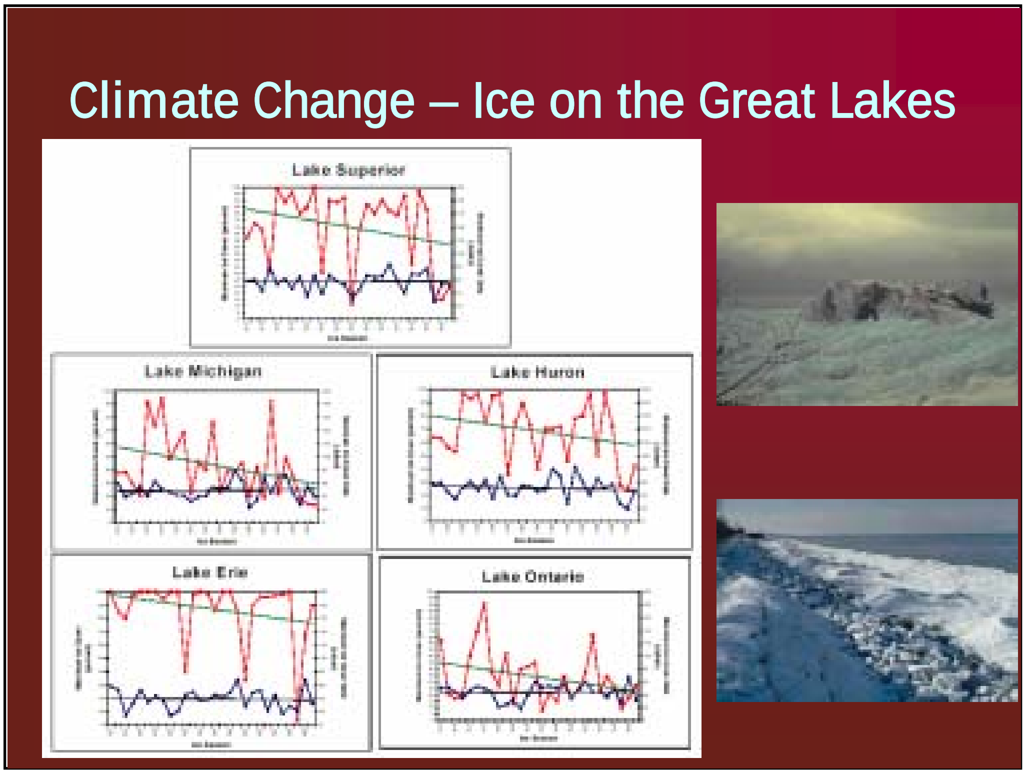
This indicator assesses the extent of hardened shoreline through the construction of sheet piling, rip rap. Or other erosion control structures. Shoreline hardening not only directly destroys natural features, but also disrupts biological communities that are dependent upon the transport of shoreline sediment by lake currents. Hardening also destroys inshore habitat for fish, birds, and other biota. Among connecting channels, the St. Clair, Detroit and Niagara Rivers have a higher percentage of their shorelines hardened than anywhere else in the basin. Of the lakes, Lake Erie hs the highest percentage of its shoreline hardened, and Lakes Huron and Superior have the lowest percentage.



The purpose of this indicator is to examine the historic water levels in all the Great Lakes and compare these levels and their effects on wetlands with water levels in Lakes Superior and Ontario, where water levels have been regulated since about 1914 and 1959, respectively. Naturally fluctuating water levels are essential for maintaining the ecological health of Great Lakes shoreline ecosystems, especially coastal wetlands. The ecosystem objective is to maintain the diverse array of Great Lakes coastal wetlands by allowing, as closely as possible, the natural seasonal, annual, and decadal fluctuations of Great Lakes water levels. The Great Lakes shoreline ecosystems are dependent upon natural disturbance processes, such as water level fluctuations, if they are to function as dynamic systems. The biological communities that populate these coastal wetlands have responded to these dynamic changes with rich and diverse assemblages of species.

Time series at Fish Point (east shore of Saginaw Bay, Lake Huron) from 1988 to 2000 showing the effects of fluctuating water levels on a coastal wetland.

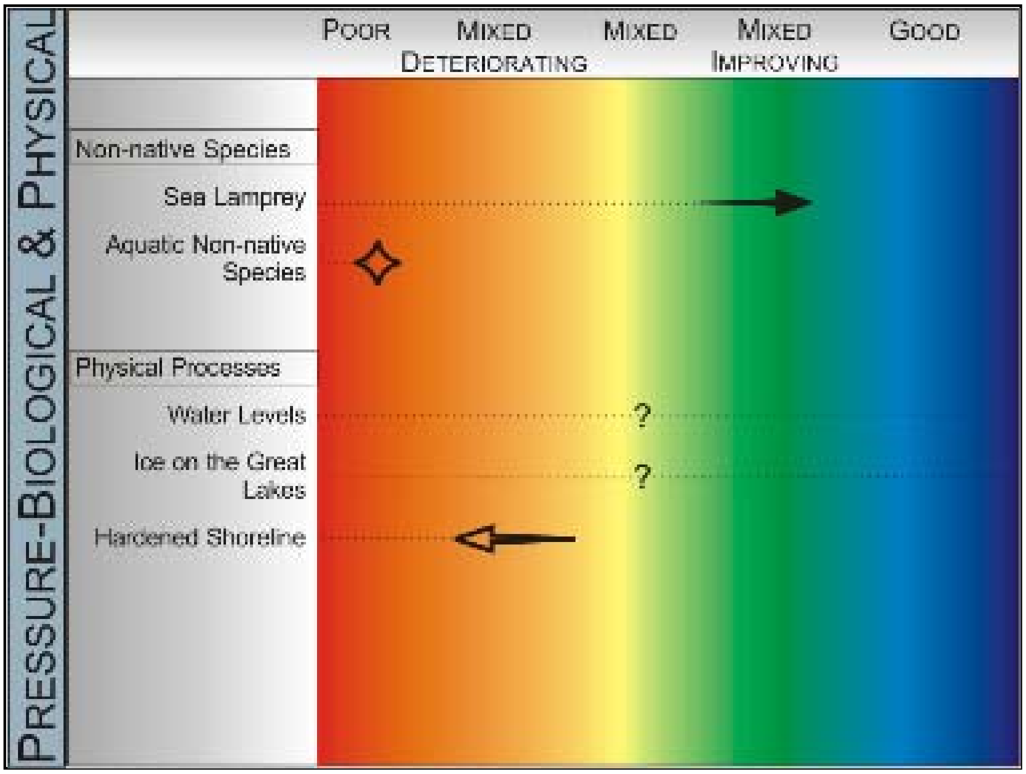
Photo credits: Douglas A. Wilcox, U.S. Geological Survey



Now let's look at the indicator for climate change, "Ice on the Great Lakes." This indicator is used as a potential assessment of climate change, particularly within the Great Lakes Basin. Changes in water and air temperatures will influence ice development on the Lakes, and in turn, affect coastal wetlands, nearshore aquatic environments, and inland environments.

Data from ice charts were collected and analyzed to determine if there has been a change in the ice cover of the Great Lakes. On a decadal scale, there appears to be a decrease in the maximum ice cover per season over the last thirty years, from the 1970's to 1980's to the 1990's. Trends show that over this time span, the maximum amount of ice forming each year has been decreasing. Between the 1970's and the 1990's, there ws at least a 10 percent decline in the maximum ice cover on each lake, and almost as much as 18 percent in some cases, with the greatest declines occurring during the 1990's.

If the predictioins of global warming are true, we can expect increased winter air temperatures and milder winters. This may lead to decreased ice cover. Milder winters can have a drastic effect on how much of the lakes are covered with ice, which in turn will have an effect on many aquatic and terrestrial ecosystems that rely on lake ice for protection and food acquisition.



Pressure indicators that I have discussed are now summarized for you in rainbow diagrams.

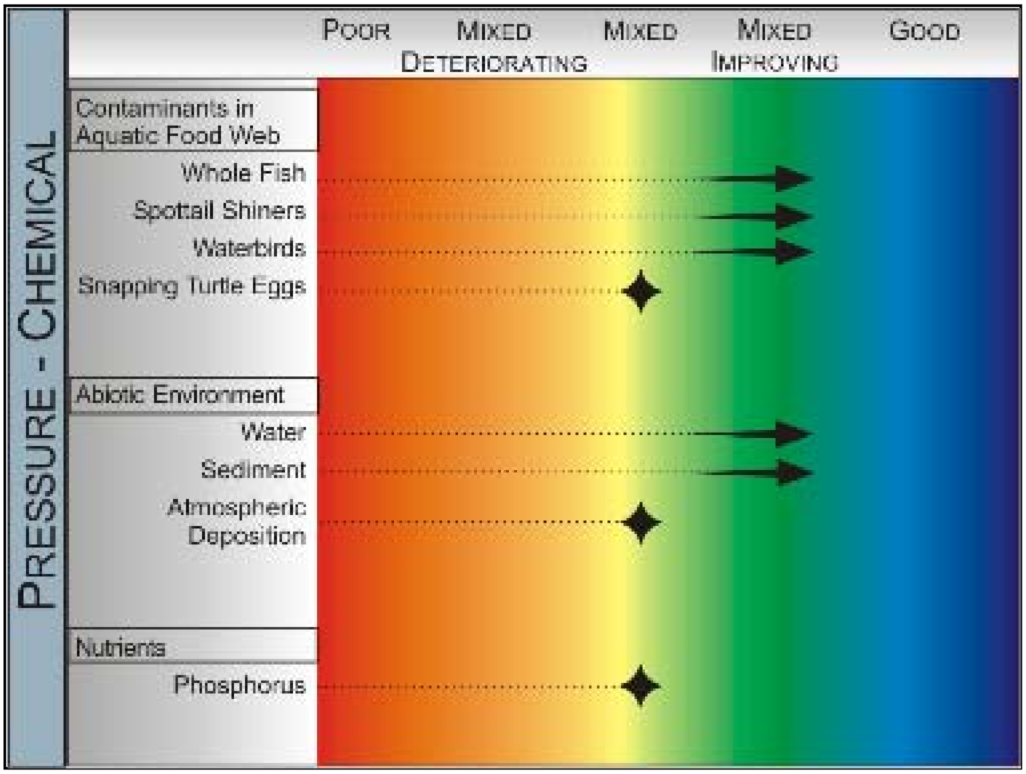
Now we will evaluate the state of the lakes In terms of pressures from non-native species and physical processes.

The status of sea lamprey indicator is considered as mixed (Lake Huron) but overall improving to an acceptable state (the other Lakes).

The indicator for aquatic non-native species is rated poor, indicating the ecosystem is severely negatively impacted and is without even minimally acceptable conditions.

The status of the climate change in the Great Lakes as measured by ice cover is trending toward a loss of ice cover, the indicator is going in the direction of deteriorating for all the Lakes.

Shoreline hardening is generally not reversible, so once a section of shoreline has been hardened, it can be considered a permanent feature. As such, the current state of shoreline hardening likely represents the best condition that can be expected in the future. Since we are unsure whether the rate of hardening can be reduced or halted, additional hardening will almost certainly continue, leading to a mixed deteriorating rating for the indicator.


PRESSURE - CHEMICAL
POOR
MIXED
DETERIORATING
MIXED
MIXED
IMPROVING
GOOD
Contaminants in Aquatic Food Web
Whole Fish
Spottail Shiners
Waterbirds
Snapping Turtle Eggs
Abiotic Environment
Water
Sediment
Atmospheric Deposition
Nutrients
Phosphorus